Towards a new timber architecture – rethinking research, development and innovation in the use of modified wood in contemporary construction

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ABSTRACT

Wood modification is a relatively mature science but outputs from research in this area have still to evolve into a range of distinctive products that go beyond being more durable replacements for existing construction components. This paper proposes a way in which architects, engineers and other construction professionals, manufacturers and scientists operating in the field of wood modification might collaborate in the development of new, unique and commercially viable modified wood products.

INTRODUCTION

There is nothing especially new about modified wood products - their physical characteristics and mechanical properties are well documented - so, given their acknowledged positive attributes, why do we see so little modified timber used in building construction around the globe today?

For environmental and other reasons, timber - in all its various forms - has in recent years attracted the attention of architects and engineers alike, but the largest market share for new/innovative products has undoubtedly been taken by engineered timbers - solid wood panels such as cross laminated timber (often referred to as CLT or X-Lam) and laminated veneered lumber (LVL) rather than by ones in which the raw material's cell structure has been modified by chemical or thermal means. Trade names such as Accoya® and Kebony® and Thermowood®– despite substantial international marketing – have arguably impacted only modestly on the construction industry to date and, were a survey to be done of architects and specifiers around the globe, it would be unlikely to reveal any significant depth of knowledge or understanding of when and where products carrying these or other modified wood trade names might be used, what the differences between them are and why they should command premium prices over other forms of timber or timber products.

THE PROBLEM

In part the problem can be attributed to education – most people who enter architecture, for example, do so from a non-scientific background and, throughout their subsequent education, generally receive very little material science input. Whilst these otherwise well trained professionals can readily understand the technical aspects of engineered timber products such as glulam – and can see and/or reference plenty of inspirational examples of these products in use – there is relatively little built evidence around of the different modified wood products available in today's highly competitive construction marketplace.

Second, there is only a modicum of understanding within the construction professions of what the term ‘wood modification’ actually means or what the difference is between chemically modified and thermally modified timber are and in what situations either of these generic materials might offer an appropriate – or indeed definitive – construction solution. All too often wood modification is referred to – or presumed to be – a coating or impregnation treatment. Clearly this is both an educational and a communication problem.

Third - and despite the substantial investment in manufacturing facilities – the range of actual modified wood products available in the marketplace can be viewed as quite limited, with cladding, decking and window systems the most obvious of those on offer and for each of which ample alternatives can be easily found, often at considerably less cost, albeit with significant performance differences. Of course there are innovative products such as MediteTricoya® but this example is seen by many as merely a superior, waterproof version of a mid-value product. Genuinely unique – and inspiring - applications are still to emerge.

Research and development has of course been carried out to manufacture engineered timber products using modified woods (such as used in the glued laminated Accoya bridge at Sneek in the Netherlands by Achterbosch Architectuur and Onix Architects), but examples of new product development designed to bring completely new and exciting products to the marketplace are hard to find. The Moses Bridge or Loopgrafbruug (Trench Bridge, at Fort de Roovere, Halsteren in the Netherlands, by RO & AD Architecten) is arguably the only recent example of modified wood in use to really capture the imagination of the international design community. So what needs to be done to change this state of affairs?

Henry Ford is reputed to have said that had the general population been asked (prior to the development and mass availability of his Model T automobile) what better form of transport they would like, the answer would likely have been ‘a faster horse’. If Ford were to address his observation today to the wood modification sector, he might well have queried whether the enormous investment of academic and industry resources that has been – and continues to be - made into the investigation of chemical and thermal modification of different wood species is really only capable of producing better performing forms of external timber cladding and decking or high performance window systems? Where is the quantum leap in innovative thinking about modified wood that Ford would have looked for likely to come from?

The global construction industry – like Ford’s public – is rarely the initiator of, or in the forefront of support for, unconventional ideas, working best (or at least extensively) with what it already knows, making modest efficiency changes in process along the way and ultimately aiming to deliver increased profit margins, with improved construction quality more often than not – and if fortunate - a by-product of this imperative. In this environment, it is arguable that most of the significant developments in the construction industry tend to emerge in response to legislative or regulatory change rather than as a result of ‘eureka’ moments that might lead to genuinely innovative products or processes.

One example of the latter is the development of cross laminated timber, a product initially conceived to address over-production in the Swiss forest industry and to deliver an added value use for low grade material. That this product has now matured into a major element in the thinking of architects and engineers around the world is down to its ability to not only replace non-renewable materials such as prefabricated concrete panels but also in the capacity of these large plates of solid wood to lock up substantial amounts of atmospheric carbon dioxide. The product has many other positive attributes

attractive to architects/specifiers and it is no surprise therefore to find engineers now considering 20-30 storey structural designs never before possible with wood construction, or that new CLT manufacturing facilities are fast emerging around the globe to make high added value use of locally grown timber.
The case being made here, therefore, is that for similar eureka moments in wood modification to occur, greater collaboration between the manufacturers and scientists involved in research in this area and the architects, engineers and designers who might well use products emanating from the processes involved would generate a more focused approach to research and product development than currently exists for these technologies. This, arguably, could produce many benefits and possible side products as yet not conceived or imagined within wood modification research.

CONTEXT

By way of corollary, space scientists in the 1960s, in their ambition to put a man on the moon, required - and demanded - a whole range of previously non-existent materials and products (or at least not formerly used for this purpose) to better build the spacecraft that could safely endure the long, hazardous journeys to and from their target. From such research a whole range of new ideas and technologies emerged that are now part of everyday products - and whilst our general awareness of pens that can write upside down and the Teflon coatings on our frying pans may just be the result of good public relations on NASA's part rather than genuine achievements from the US space programme – it is undoubtedly the case that, in the quite extraordinary scientific and technological environment that emerged in that decade, technological advances made then have since been applied to purposes that could not have been imagined at the time.
Similarly, within the construction industry, the role that architects, engineers and designers then and since have played in taking outstanding but unapplied scientific research into other areas – glass technology being an obvious example – has been crucial to advances made. Architects such as Ian Ritchie and engineers like Tim MacFarlane have pushed the boundaries in this field to the point where we now regard large-scale self-supporting glass structures and self-cleaning glazing systems on high-rise buildings as commonplace. Similarly, architect Hugh Broughton has applied technology developed for the space programme to buildings capable of performing successfully in the worst Antarctic conditions. And Lord Foster has long been an advocate for the use of advanced materials in building construction – even to the point of using wood in high-tech ways. These individuals have built successful careers on working with scientists and manufacturers to conceive, and make commercially viable, new products and systems that have fundamentally changed the way we think about construction. What is now needed is to identify the design talent that can help deliver quantum leaps in the way we think about - and apply – the science involved in modifying wood to new and highly innovative construction products.

THE PROPOSITION

There are many other issues (including cost), of course, that currently mitigate against greater use of modified woods, but a key aspect to be addressed in endeavours to see them more widely specified must surely be how to increase designer engagement, *i.e.* how best to encourage architects, engineers and others to explore new ways of utilising these exceptional materials. No matter how many good examples of external cladding, decking or laminated window frames made from modified wood are highlighted, the cold hard reality is that these are simply not the things to get designers' juices flowing. It is not a question of attitudes (whether positive or negative) towards modified wood or of proving how durable or cost effective over the life cycle they might be in comparison with sawn timber, but more a matter of demonstration – to clearly show what distinguishes these materials from the many others that are available to the construction industry and how their special characteristics might be reflected – and indeed developed - in the design of buildings or in the creation of new construction or other products.

Herein lies the challenge for modified wood manufacturers and researchers –focus and discussion now need to move beyond investigations into chemistry and manufacturing processes to an entirely new position where the inherent potential of these materials begins to be realised in novel and perhaps visionary design applications: an exploratory process in which *product development* is paralleled by *professional development* within the construction and manufacturing communities. This is a route to market that requires scientists and manufacturers to work directly with architects and engineers to discover new opportunities for modified woods and, in doing so, to move far beyond the limited product range that is currently available. This is not to suggest that huge new levels of investment are required, but more a plea to match scientific knowledge, talent and experience with the equivalent attributes to be found within the design community in a combined drive to imagine new product possibilities and ways of working with modified wood.

Not all architects and engineers are suited to this demanding task, of course – architecture nowadays is invariably an arts-based education and has no more an academic research culture than it has the material science education referred to earlier. Put simply, the study of architecture is one of the few general educations still available and graduates of this discipline enter the construction industry with knowledge and broad abilities in many areas (construction, design, history, sociology, urbanism to name but a few) but with relatively low levels of specialized skills at this early stage in their careers.

In most UK university schools of architecture, for example, postgraduate academic research - such as exists - is more often focused on aspects of historical investigation and design theory than on the development and testing of construction products and systems. Civil and structural engineering undergraduate and postgraduate education and subsequent research is certainly more focused on material development, but the predominant engineering emphasis universally remains on concrete and steel construction rather than on any aspect of timber.

And, as with all disciplines, there are leaders and there are followers – the former emerging as the creative stars of their respective professions and the latter tending to draw inspiration from these pathfinders' achievements. Haiko Meijer of Groningen-based architects Onix, for example, has for many years been a highly vocal advocate of modified wood and has produced outstanding architectural examples that have undoubtedly encouraged others to explore the potential of the technology. Similarly, Alex de Rijke of London based architects dRMM and Professor and Dean of the School of Architecture at the capital's Royal College of Art has been in the forefront of a research and development culture emerging in the UK that continues to address the potential of cross laminated timber. And Andrew Waugh of Waugh Thistleton Architects in London has led the charge to taller and taller buildings constructed from solid, structural timber – a charge that is now taking place on the global stage.

The point being made here is that some architects have not only been leaders – they have effectively been champions - evangelists even - for designing with timber in all its forms. And they have worked closely with engineers, manufacturers, scientists and

academics to push boundaries and in doing so have engaged the attention of many of their fellow professionals who have then sought to emulate and sometimes exceed their constructed achievements. To date, however, there have been too few creative champions for modified wood, a situation that needs to be seriously addressed if the technologies involved are to gain greater appeal and subsequent widespread acceptance.
And there is a lesson in this for manufacturers - the culture of the construction industry is highly unlikely to be changed through advertising, marketing or manufacturer-led continuing professional development (CPD) seminars alone. No matter what guarantees and warranties are provided on products, architects and engineers are nevertheless professionally required to carry substantial indemnity insurance cover on their work and as a result are often cautious about the inclusion of new and relatively untested technologies, materials and components in their projects. Possibly more than any other construction profession, the majority of architects want to see physical examples of materials and products in use before deciding to integrate them into their own designs. And all this before the vexed question of cost is introduced into the project equation.
How might the development of a wider range of demonstration projects be achieved therefore? The premise made earlier in this paper suggested that a new approach was required - an exploratory process in which *product development* is paralleled by *professional development* within the construction and manufacturing communities. Work carried out at Edinburgh Napier University over the past three years has allowed this concept to be tested, with the results achieved quantified. From this evidence it is now possible to consider how a similar process might be applied to the further development of modified wood applications for construction. The project referred to - 'The Wood Products Innovation Gateway' (WPIG) - was financially supported by the European Regional Development Fund (ERDF) with match funding from Scottish Enterprise, Forestry Commission Scotland, ConFor (the Confederation of Forest Industries) and Wood for Good. This support enabled a three year, €1,782,000 programme to be initiated with the aim of delivering 20+ new products, process improvements or construction systems from Scottish grown timber, to establish 20+ new research networks and to engage with 600+ small to medium enterprises (SMEs).
The WPIG project concludes at the end of March 2014 with all of these targets either met or exceeded, but more importantly, it has brought architects and engineers together with foresters, sawmillers, manufacturers, wood scientists and building contractors and has communicated the outputs of the resultant studies, tests and prototype developments to a wide audience of construction professionals through an extensive continuing professional development (CPD) programme. This parallel process has engendered widespread discussion and awareness of the programme's resources and ambitions, resulting in further suggestions for commercially viable product development. As a result, it is now possible to look forward to the creation of some very large-scale industrial manufacturing and assembly facilities with significant, positive impact on the economy of Scotland's forestry and timber processing sectors whilst, at the other end of the spectrum, to the manufacture - often in rural locations - of relatively small, niche manufacturing with real potential to contribute to the sustainability of local communities and economies. Overall, the average research and development costs per product/construction system have been relatively low due to programme's ability to generate investment in kind (time, manpower, equipment and materials) from the forestry, timber and construction industries.
Much of the work involved has, perhaps inevitably, focused on the development of engineered timber products and construction systems, but in doing so the WPIG project has also been able to instil an awareness of the potential uses of Scottish grown timber

amongst its immediate constituency of construction professionals and this has had a measurable benefit to the timber processing and manufacturing sector. It is anticipated that WPIG's aspirations and the collaborative processes established as a result will continue well into the future, with further financial support from the match funding stakeholders and from the timber industry itself, the latter of which now better understands the benefits to be gained from sustained investment in focused research and development.

APPLICATION

How might this model be applied to the wider world of wood modification in which the investment cost of research and development has traditionally been high? The Wood Products Innovation Gateway was predicated upon a perceived need to inform and inspire architects and engineers about timber in all its forms and, having then inspired them to design with wood, to provide them with continuing objective and independent technical support on actual design projects. From such foundations good practice and experience can be generated and, with the collaborative experience and knowledge thus derived, experience has shown that it is then possible to identify those architects and engineers most interested in – and capable of - exploring the use of timber materials/products more creatively.

This process has resulted in the identification of a number of innovative approaches with commercial potential that, with allocations of relatively small sums of money to each, have then been supported through feasibility studies, market assessments, prototyping and testing. A singular advantage of this process is that it is, to a large extent, market-led - *i.e.* the designers involved have recognised a potential gap in the material/product ranges currently available and the possibility of developing a wood-based solution or alternative. This is a world away from architects and other construction professionals being seduced by manufacturers' hyperbole about their products in that it takes innovative and often highly individual ideas through a process tailored to delivering objective, evidence-based results founded upon good science and engineering principles.

One interesting example from the Wood Products Innovation Gateway is actually a modified wood product – laminated timber beams manufactured using Accoya®. It should be noted here that over 70% of new housing in Scotland is constructed using platform timber frame technology that is generally built upon *in-situ* concrete pad or strip foundations. The possibility of extending the use of timber by using a highly durable material in situations where there is ground contact offered a new product development opportunity. This has resulted in the prototype manufacture of glued laminated Accoya® ground beams that were subsequently installed in Dunsmore House, a new construction in the Scottish Highlands designed by Neil Sutherland Architects and which is now undergoing extensive monitoring to assess the product's overall technical performance. A small example perhaps, but with demand for new housing growing exponentially in the UK (upwards of 250,000 houses per year are required according to the UK Government) and - with the likelihood of greater unit numbers being prefabricated offsite (for reasons of speed, construction accuracy and ever-increasing standards of airtightness and thermal insulation) - the need for more efficient and lighter weight foundation structures is paramount.

The point being made here is that there are many such opportunities across the global construction industry – some may be quite mundane but nevertheless may well result in high volume, commercially viable products, whilst others have the potential take modified wood into new and exciting territory. The above example is a simple structural application that makes use of previously tried and tested technology, but it is the combination of this – glue lamination - with the inherent structural properties of an appropriate acetylated timber species (Southern Yellow Pine) to deliver a product capable of meeting Service Class 2 or 3 conditions (Eurocode 5) that provides the step change.

DISCUSSION

In examining how a relationship between *product development* and *professional development* can be built upon the foundation of the vast amount of past and current research into wood modification that has taken place around the globe, it is relevant to mention that the model described here was developed specifically for an identified situation in Scotland, the location of the largest part of the UKs forest resource and a significant element in the smaller country's economy. It is also important to recognise that the WPIG project has been led by architects and engineers working in academia and who have coordinated the relationship between academics, practising construction professionals, forest, timber and construction industry members and funding bodies.

In applying this model to the world of wood modification, it can be seen that similar challenges exist, albeit on a larger, more geographically widespread scale and with different proportions to the participating groups. In Scotland, the largest group involved - the SME sector – has largely comprised construction professionals as this was recognised as the audience that not only required objective information but which, once armed with this knowledge, could also provide the creative charge to conceive new products and systems. From this starting point other groups – foresters, processors, manufacturers, contractors, furniture makers, *etc.* (all based in Scotland) – have been invited to participate in specific research and development projects, with other possible project ideas posited by members of any of these latter groups/sectors also afforded support for feasibility studies and subsequent development.

In conceiving a mechanism designed to extend the construction possibilities inherent in wood modification it should be noted that although the first target audience is largely the same – albeit in much greater numbers and located in multiple countries – the number of people involved in academic/scientific research is also considerable and global, whilst the number of possible manufacturers is, for well understood reasons, extremely limited. Of these groupings, the scientific community already has well-established conferences and networks such as ECWM and COST Actions, but the mechanism necessary to deliver the knowledge transfer that will allow it to reach and engage with the other categories mentioned above (aside from manufacturers) remains to be put in place.

A further key question to be addressed when conceiving the mechanism discussed here is whether or not it should have a clear, well-defined focus to its work or allow for a wider range of possibilities to emerge? Experience suggests the emphasis should, in the first instance, be on construction opportunities since this is more likely to engage funding and partner support and indeed to respond to other areas of research currently underway internationally such as 'Wood Be Better', a Norwegian initiative designed to explore and encourage greater use of timber in urban construction.

CONCLUSION

In conclusion, therefore, how to create a mechanism that highlights wood modification's potential to a wide audience of construction professionals, to filter down from this to those who have ideas and/or the creative skills to work with scientists and other interested parties to develop innovative, new modified wood products and to then disseminate knowledge of these back to the primary audience in order to deliver new markets is the challenge for us all. Can this be the decade when wood modification finally comes of age and develops a genuinely distinctive – indeed unique and commercially successful - position for itself in the wider world of construction?

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